

Distribution of Lessepsian Migrant and Non-Native Freshwater Fish Species in Mediterranean Brackish Waters of Turkey

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Research Article

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Abstract

The introduction of invasive fish species is considered to be one of the major causes of species endangerment in aquatic ecosystems. More than 30 non-native freshwater fish species which are introduced for the different purpose were reported in Turkey. In addition to the freshwater non-native fish species, the brackish water systems are also affected by the fish species that enter the Mediterranean Sea through the Suez Canal. This study aimed to identify non-native fish species introduced in the Mediterranean brackish water systems of Turkey. Thirteen non-native species from eleven families were identified from 15 localities along the entire Mediterranean Coast of Turkey between 2014-2017. These species are *Carassius gibelio* (Bloch, 1782), *Pseudorasbora parva* (Temminck & Schlegel, 1846), *Coptodon zillii* (Gervais, 1848), *Oreochromis niloticus* (Linnaeus, 1758), *Gambusia holbrooki* Girard, 1859, *Oncorhynchus mykiss* (Walbaum, 1792), *Chelon carinatus* (Valenciennes 1836), *Equulites klunzingeri* (Steindachner, 1898), *Upeneus moluccensis* (Bleeker, 1855), *Upeneus pori* Ben-Tuvia & Golani, 1989, *Siganus rivulatus* Forsskål & Niebuhr, 1775, *Sillago suezensis* Golani, Fricke & Tikochinski, 2013 and *Sphyræna chrysotaenia* Klunzinger, 1884. The most widely distributed non-native fishes were *Gambusia holbrooki*, *Chelon carinatus*, and *Carassius gibelio*. Of the 15 localities surveyed Lessepsian fish species were sampled from 9 localities.

Keywords: Lessepsian species, biological invasion, fish fauna, biodiversity

Türkiye'nin Akdeniz Acısularında Lesepsiyen göçmen ve yabancı tatlısu balık türlerinin dağılımı

Özet

İstilaçı balık türlerinin sistemlere girmesi, sucul ekosistemlerde türlerin tehlikeye girmesinin başlıca nedenlerinden biri olarak kabul edilmektedir. Türkiye'de farklı amaçlarla sucul sistemlere giren 30'dan fazla yabancı tatlı su balığı türü bildirilmiştir. Yabancı tatlısu balık türlerine ek olarak, acısu sistemleri Süveyş Kanalı aracılığı ile Akdeniz'e giren balık türlerinden de etkilenmektedir. Bu çalışmanın amacı, Türkiye'nin Akdeniz acısu sistemlerinde bulunan yabancı balık türlerini belirlemektir. 2014-2017 yılları arasında Türkiye'nin Akdeniz kıyılarında 15 farklı çalışma alanında onbir familyadan 13 yabancı tür tespit edilmiştir. Bu türler *Carassius gibelio* (Bloch, 1782), *Pseudorasbora parva* (Temminck & Schlegel, 1846), *Coptodon zillii* (Gervais, 1848), *Oreochromis niloticus* (Linnaeus, 1758), *Gambusia holbrooki* Girard, 1859, *Oncorhynchus mykiss* (Walbaum, 1792), *Chelon carinatus* (Valenciennes 1836), *Equulites klunzingeri* (Steindachner, 1898), *Upeneus moluccensis* (Bleeker, 1855), *Upeneus pori* Ben-Tuvia & Golani, 1989, *Siganus rivulatus* Forsskål & Niebuhr, 1775, *Sillago suezensis* Golani, Fricke & Tikochinski, 2013 ve *Sphyræna chrysotaenia* Klunzinger, 1884'dır. En yaygın dağılıma sahip yabancı balıklar *Gambusia holbrooki*, *Chelon carinatus* ve *Carassius gibelio*'dur. İncelenen 15 sistemden 9'unda Lesepsiyen balık türleri örneklenmiştir.

Anahtar Kelimeler: Lesepsiyen türler, biyolojik istila, balık faunası, biyoçeşitlilik

INTRODUCTION

Estuaries, lagoons, and coastal ponds are known as brackish water systems, which are associated with freshwater and the sea. Brackish water fish assemblages are adapted to live under highly variable environments. Brackish water systems are usually recognized by the presence of habitats with conservation interest. In addition to the ecosystem regulatory properties, the brackish water systems play a key role as feeding, spawning, and breeding area for many species (Mc Dowall, 1988; Malavasi et al., 2004). Fish assemblages of brackish water systems have been studied extensively in the last four decades (Blaber, 1980; Elliott and Dewailly, 1995; Kennish, 1990; Potter et al., 1990; Jaureguizar et al., 2006; Miró et al., 2020; Schwartzkopf et al., 2020).

There are 25 river catchment basins in Turkey and 18 of them have important coastal marine areas. The Mediterranean region of Turkey has many important lagoon lakes and rivers whose fishery resources play a significant role in the economy of the local populations. Various aspects of the fish assemblages in the brackish water systems of Turkey have been studied in recent decades, including temporal and spatial patterns in abundance and diversity of fishes (Akın et al., 2005; İnnal, 2012a; İnnal, 2016), systematics (Engin and İnnal, 2017), and length-weight relationships (İnnal and Özdemir, 2012; Kara et al., 2018).

As reported in other Mediterranean countries (Anonymous, 2012; Cataudella et al., 2015; Maneas et al., 2019) there are human impacts on the brackish water systems of Turkey as well. These systems have been affected by large-scale anthropogenic influences, mainly the substantial development of tourism activities and the increasing population in the catchment (Bayhan et al., 2008; İnnal, 2012a). Biological invasions in the brackish water systems of Turkey have accelerated in recent years. Many non-native species from different taxonomical groups have been found in the brackish water systems of Turkey (Saitsev and Öztürk, 2001; Öztürk and Özer, 2014; Türeli et al., 2016). In Turkey, the introduction of non-native freshwater fish species dates back to the 1920s, when eastern mosquitofish was introduced into the Çukurova region. To date, more than 30 non-native fish species have been introduced. Studies have been conducted into different aspects of the non-native species, including their distributions (Emiroğlu, 2011; İnnal, 2012b, Tarkan et al., 2015; Özuluğ et al., 2019), impacts on fish communities (İnnal and Erk'akan, 2006; Yerli et al., 2013; Kurtul and Sarı, 2017; İlhan et al., 2020), and biological features (Saç and Okgerman, 2015; Cılbız and Yalım, 2017; İnnal et al., 2019). In addition to non-native freshwater fish, the Lessepsian marine fish also threaten Mediterranean brackish water systems. Despite the prevalence of studies documenting the native fishes of the brackish water systems in the Mediterranean, there have been few reports of non-native species. The purpose of the study was to analyze the occurrence and distribution of non-native fishes established in the brackish water systems of Turkey.

MATERIALS and METHODS

The study was carried out from November 2014 to June 2017 in brackish water systems along the entire Mediterranean coast of Turkey. A total of 15 localities, representing a variety of habitats (including mouths of river and creeks, canals of rivers, and lagoonal areas), were repeatedly surveyed. Sampling sites with their locality and habitat description are given in Table 1.

Table 1. Sampling sites with their locality and habitat description

No	Locality	Type	Substrates	Flow velocity	Coordinates	
1	Köyceğiz, Köyceğiz (Muğla)	Lagoon lake	gravel-silt-sand	Stagnant	36°57'30.45"N	28°40'30.46"E
2	Beymelek, Demre (Antalya)	Lagoon lake	silt-sand	Stagnant	36°16'26.25"N	30° 3'15.01"E
3	Kopak, Aksu (Antalya)	Open creek estuary	silt-sand	Slow	36°51'7.27"N	30°52'1.87"E
4	Beşgöz, Serik (Antalya)	Open creek estuary	silt-sand	Slow	36°51'21.89"N	30°56'39.81"E
5	Köprüçay, Serik (Antalya)	Open river estuary	gravel-silt-sand	Fast	36°49'46.82"N	31°10'26.82"E
6	Manavgat, Manavgat (Antalya)	Open river estuary	silt-sand	Fast	36°44'18.42"N	31°29'38.43"E
7	Karpuzçay, Manavgat (Antalya)	Semi-closed creek estuary	silt-sand	Slow	36°42'56.84"N	31°33'00.95"E
8	Hacımus, Gazipaşa (Antalya)	Open creek estuary	gravel-silt-sand	Slow	36°15'45.14"N	32°16'46.54"E
9	Sultansuyu, Anamur (Mersin)	Open creek estuary	gravel-silt-sand	Slow	36° 2'15.42"N	32°49'8.11"E
10	Paradeniz, Silifke (Mersin)	Lagoon lake	silt-sand	Stagnant	36°18'27.51"N	34° 0'39.00"E
11	Göksu, Silifke (Mersin)	Open river estuary	silt-sand	Fast	36°17'46.24"N	34° 2'42.75"E
12	Berdan, Tarsus (Mersin)	Open river estuary	silt-sand	Moderate	36°44'53.83"N	34°53'29.27"E
13	Seyhan, Tarsus (Mersin)	Open river estuary	silt-sand	Fast	36°43'50.61"N	34°54'45.74"E
14	Ceyhan, Karataş (Adana)	Open river estuary	silt-sand	Fast	36°34'10.83"N	35°33'36.15"E
15	Yelkoma, Yumurtalık (Adana)	Lagoon lake	silt-sand	Stagnant	36°42'27.30"N	35°40'36.72"E

Sampling localities are given in the map below (Figure 1). Google Earth photographs of localities are given in Figure 2.

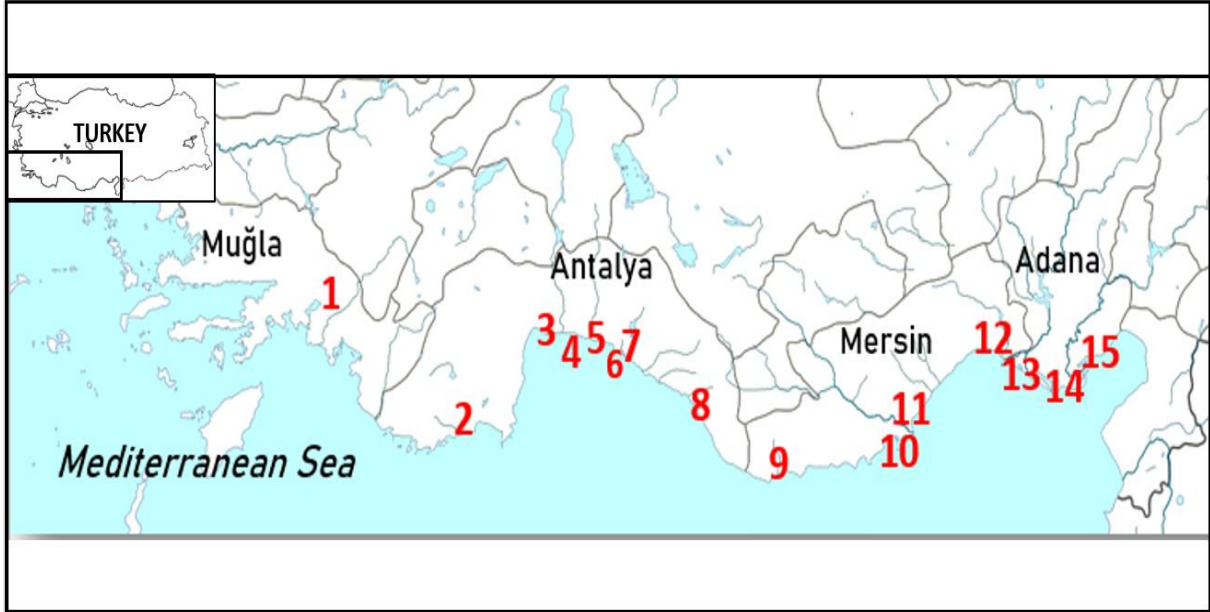


Figure 1. Sampling localities of brackish water systems in the Mediterranean coast of Turkey
 1-Köyceğiz lagoon lake; 2- Beymelek lagoon lake; 3- Kopak creek estuary; 4- Beşgöz creek estuary; 5- Köprüçay river estuary; 6- Manavgat river estuary; 7- Karpuzçay creek estuary; 8- Hacımusa creek estuary; 9- Sultansuyu creek estuary; 10- Paradeniz lagoon lake; 11- Göksu river estuary; 12- Berdan river estuary; 13- Seyhan river estuary; 14- Ceyhan river estuary; 15- Yelkoma lagoon lake

Details (Type, substrate structure, flow regime) of localities were recorded. The non-native ichthyofauna of the systems was sampled using Shore seine net (10 m in length and 2 m in height; 1.2 x 2.0 mm mesh sized) in all localities. Besides, gill nets in different mesh sizes (310 m in total length; 10, 17, 23, 30 mm bar lengths), cast nets, and fish traps were used in four localities (Manavgat, Göksu, Seyhan, and Ceyhan river estuaries). Fish species were identified according to Akşiray, 1987; Geldiay and Balık, 1988; Kottelat and Freyhof, 2007, Turan et al., 2007.



Figure 2. Google Earth photographs of localities (1-Köyceğiz lagoon lake; 2- Beymelek lagoon lake; 3- Kopak creek estuary; 4- Beşgöz creek estuary; 5- Köprüçay river estuary; 6- Manavgat river estuary; 7- Karpuzçay creek estuary; 8- Hacımusa creek estuary; 9- Sultansuyu creek estuary; 10- Paradeniz lagoon lake; 11- Göksu river estuary; 12- Berdan river estuary; 13- Seyhan river estuary; 14- Ceyhan river estuary; 15- Yelkoma lagoon lake)

RESULTS

The systematic status of the non-native fishes in brackish water systems are given in Table 2. Origin and introduction ways of species are given in Table 3. Non-native fishes inhabited in the sampling localities are given in Table 4. Numerical evaluation of locality and non-native species is given in Figure 3.

Table 2. Systematic status of the non-native fishes in brackish water systems

No	Species	Name	Family	Order
1	<i>Carassius gibelio</i> (Bloch, 1782)	Prussian carp	Cyprinidae	Cypriniformes
2	<i>Pseudorasbora parva</i> (Temminck & Schlegel, 1846)	Stone moroko	Gobionidae	Cypriniformes
3	<i>Coptodon zillii</i> (Gervais, 1848)	Redbelly tilapia	Cichlidae	Perciformes
4	<i>Oreochromis niloticus</i> (Linnaeus, 1758)	Nile tilapia	Cichlidae	Perciformes
5	<i>Gambusia holbrooki</i> Girard, 1859	Eastern mosquitofish	Poeciliidae	Cyprinodontiformes
6	<i>Oncorhynchus mykiss</i> (Walbaum, 1792)	Rainbow trout	Salmonidae	Salmoniformes
7	<i>Equulites klunzingeri</i> (Steindachner, 1898)		Leiognathidae	Perciformes
8	<i>Chelon carinatus</i> (Valenciennes 1836)	Keeled mullet	Mugilidae	Mugiliformes
9	<i>Upeneus moluccensis</i> (Bleeker, 1855)	Goldband goatfish	Mullidae	Perciformes
10	<i>Upeneus pori</i> Ben-Tuvia & Golani, 1989	Por's goatfish	Mullidae	Perciformes
11	<i>Siganus rivulatus</i> Forsskål & Niebuhr, 1775	Marbled spinefoot	Siganidae	Perciformes
12	<i>Sillago suezensis</i> Golani, Fricke & Tikochinski, 2013		Sillaginidae	Perciformes
13	<i>Sphyraena chrysotaenia</i> Klunzinger, 1884	Yellow stripe barracuda	Sphyraenidae	Perciformes

Table 3. Origin and introduction ways of species

No	Species	Region of origin	Habitat of origin	Purpose of introduction
1	<i>Carassius gibelio</i>	Asia	Freshwater	Accidental transfer
2	<i>Pseudorasbora parva</i>	Far East	Freshwater	Accidental transfer
3	<i>Coptodon zillii</i>	Africa	Freshwater	Unknown
4	<i>Oreochromis niloticus</i>	Africa	Freshwater	Aquaculture (Farm escape)
5	<i>Gambusia holbrooki</i>	North America	Freshwater	Biological Control
6	<i>Oncorhynchus mykiss</i>	North America	Freshwater	Aquaculture (Farm escape), weed control
7	<i>Equulites klunzingeri</i>	Indo-Pacific	Marine	Lessepsian migration
8	<i>Chelon carinatus</i>	Indo-Pacific	Marine	Lessepsian migration
9	<i>Upeneus moluccensis</i>	Indo-Pacific	Marine	Lessepsian migration
10	<i>Upeneus pori</i>	Indo-Pacific	Marine	Lessepsian migration
11	<i>Siganus rivulatus</i>	Indo-Pacific	Marine	Lessepsian migration
12	<i>Sillago suezensis</i>	Indo-Pacific	Marine	Lessepsian migration
13	<i>Sphyraena chrysotaenia</i>	Indo-Pacific	Marine	Lessepsian migration

Table 4. Non-native fishes established in the sampling localities

Locality	Species												
	<i>Gambusia holbrooki</i>	<i>Chelon carinatus</i>	<i>Carassius gibelio</i>	<i>Oreochromis niloticus</i>	<i>Pseudorasbora parva</i>	<i>Sillago suezensis</i>	<i>Siganus rivulatus</i>	<i>Equulites klunzingeri</i>	<i>Coptodon zillii</i>	<i>Oncorhynchus mykiss</i>	<i>Upeneus moluccensis</i>	<i>Upeneus pori</i>	<i>Sphyaena chrysoaenia</i>
Manavgat	√	√	√		√	√	√			√	√	√	√
Beşgöz	√	√	√		√	√	√						
Göksu	√	√	√	√		√							
Seyhan	√	√	√	√				√					
Ceyhan	√	√		√		√							
Kopak	√	√	√		√								
Köprüçay	√	√	√		√								
Paradeniz	√	√		√				√					
Köyceğiz	√								√				
Beymelek	√						√						
Berdan	√			√									
Karpuzçay	√												
Hacımusa	√												
Sultansuyu	√												
Yelkoma	√												

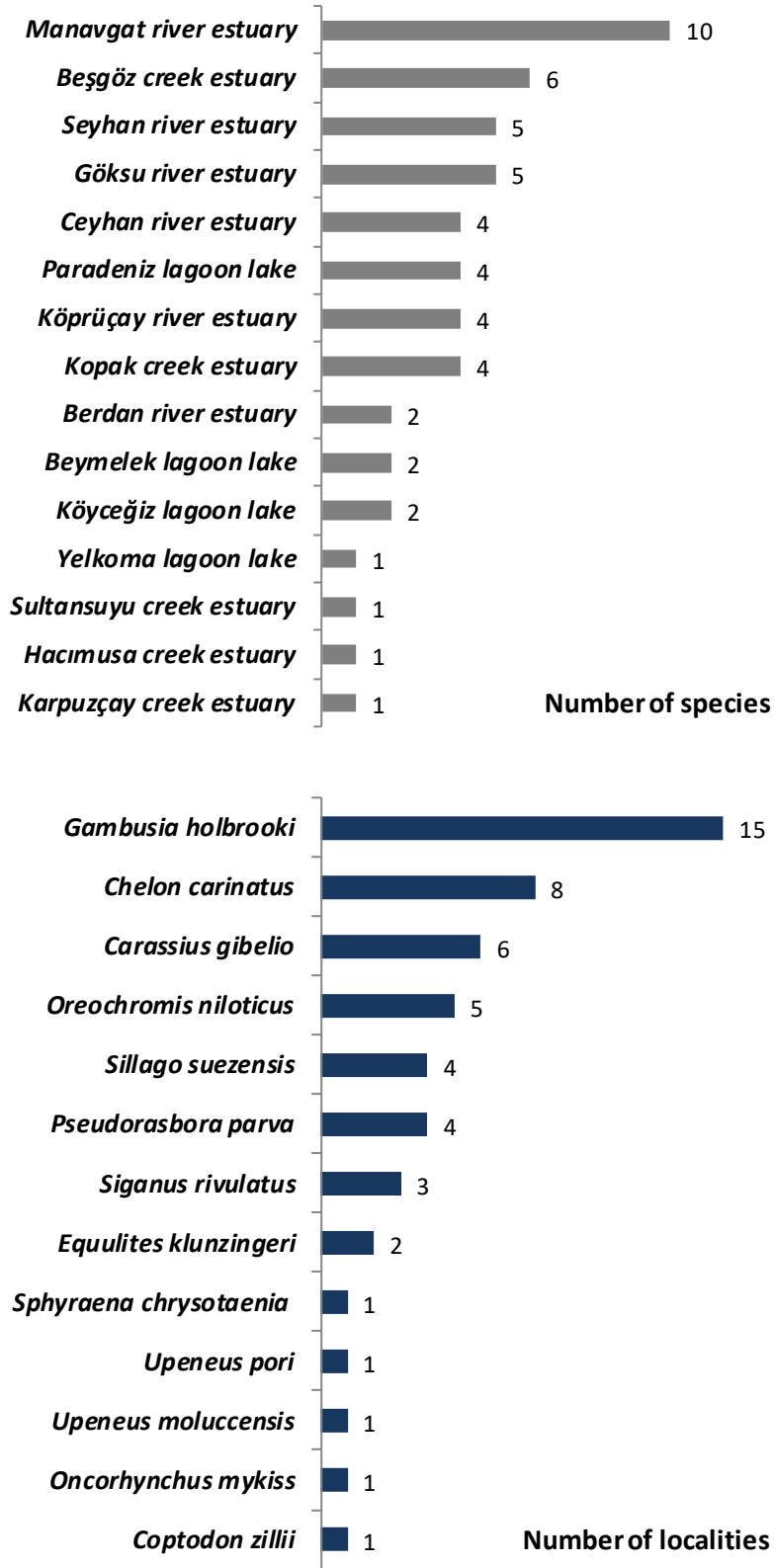


Figure 3. Numerical evaluation of locality and non-native species

Non-native species have been identified in all brackish water systems examined. The 13 non-native fish species collected represent 5 orders, 11 families, and 12 genera (Table 2). The most species-rich orders were Perciformes (61.5%), followed by Cypriniformes (15.4 %). Seven of the non-native

species originate from Indo-Pacific, 2 from Africa, 2 from North America, and 1 each from Asia and the Far East (Table 3). The numbers and distributions of the non-native species have differed between these water systems. In the studied systems, non-native fish species richness ranged from 1 to 13 (Table 4).

The most widely distributed non-native species were *Gambusia holbrooki*, present in 15 localities, and *Chelon carinatus* which was registered in 8 localities. The highest number of non-native species (10) was sampled from the Manavgat River Estuaries (Figure 3).

DISCUSSION

Brackish water systems create special ecological habitats for many fish species. They play an essential role in the nursery function of many species, especially for marine fish. These ecosystems generally provide high food availability and good predator refuge for the early life stages of these fishes (Miró et al., 2020). It has been determined that the brackish water systems analyzed in this study are important areas for the life periods of marine, estuarine, and freshwater native fishes. Some gobiid [*Gobius paganellus* Linnaeus, 1758; *Gobius niger* Linnaeus 1758; *Pomatoschistus anatoliae* Engin & Innal 2017; *Knipowitschia byblisia* Ahnelt 2011; *Knipowitschia caunos* Ahnelt 2011) and blenniid [*Parablennius sanguinolentus* (Pallas 1814); *Salaria fluviatilis* (Asso, 1801); *Salaria pavo* (Risso 1810)] fish species live in these studied region. Brackish water systems analyzed in this study also contain important habitat for migrant species including the European eel *Anguilla anguilla* (Linnaeus, 1758) and Twaite shad *Alosa fallax* (Lacepède, 1803).

Brackish water systems selected in this study belong to five different water basins (Western Mediterranean, Antalya, Eastern Mediterranean, Seyhan and Ceyhan water basins). These water basin systems characterised by a high degree of endemism of freshwater fishes (Küçük et al., 2007; Erk'akan and Özdemir 2011) and some of them were described more recently (Turan et al., 2013; Engin and Innal, 2017; Küçük et al., 2017). These systems have undergone dramatic changes in recent years. These changes occurred in the river drainage basin involving the migration barriers, industrialization, pollution, agricultural developments, introduction and invasion of non-native species (Akbulut et al., 2009; Davutluoğlu et al., 2011; Demirel et al., 2011).

Non-native fish introductions in these water basins have been accelerated in recent decades by increasing human activities such as aquaculture and fisheries. Some non-native species threatening the life of natural fish species have been reported in these river basins (Gökoğlu et al., 2001; Küçük and İkiz, 2004; Kara et al., 2010; Erk'akan and Özdemir, 2011; Ergüden and Göksu, 2012; Özuluğ et al., 2013). In this study, the most encountered non-native fish species in the localities was *Gambusia holbrooki*. It is thought that the Eastern mosquitofish were released for the solution of the intense mosquito problem in the regions where the study was conducted. It was introduced to numerous pond, drainage canals and swamps in Çukurova region (Turkey) to control malaria in 1920s (Öztürk and İkiz, 2004; Innal and Erk'akan, 2006). *G. holbrooki* has been previously reported in the Seyhan river basin (Kara et al., 2010; Erk'akan and Özdemir, 2011; Ergüden and Göksu, 2012), Ceyhan river basin (Kara et al., 2010; Erk'akan and Özdemir, 2011), Antalya river basin (Küçük and İkiz, 2004) and Western Mediterranean basin (Balık et al., 2005).

The other fish species commonly found in the studied systems is *Carassius gibelio*. It was probably dispersed into studied systems with carp (*Cyprinus carpio*) stocking program of natural and artificial lakes on water drainages. It was first observed from Gala Lake in Turkey. Since then the distribution of the species has increased greatly (Özuluğ et al., 2004; Yerli et al., 2014). According to Yerli et al., (2014) *C. gibelio* was recorded in 22 of 26 river basins of Turkey. It was detected in six different regions in this study. These regions are Kopak creek estuary, Beşgöz creek estuary, Köprüçay river estuary, Manavgat River estuary, Göksu River estuary, and Seyhan River estuary. It has been observed that *C. gibelio* creates reproducible populations in these brackish water systems, which have different chemical and biological structures.

Oreochromis niloticus has been detected in 5 (Paradeniz lagoon lake, Göksu river estuary, Berdan creek estuary, Seyhan river estuary and Ceyhan river estuary) of the 15 regions. It was reported that *O. niloticus* found in Seyhan River (Dikel and Çelik, 1998), Asi River (Gürlek, 2004), Damsa Dam Lake (Mert and Çiçek, 2010), Sakarya river basin (Emiroğlu, 2011), Pınarbaşı Creek (Burdur) (İnnal and Sungur, 2009). *Oreochromis* species escaped from the breeding units in the Seyhan Dam Lake and found the opportunity to live on the Seyhan River (Dikel and Çelik, 1998). Also, *Oreochromis* species

were used to solve the weed problems in some water channels in the Çukurova region (D. Innal, pers. observation). *Oreochromis* species have expanded their dispersal ranges in Adana and Mersin Provinces by moving through canals and other aquatic connections created by humans.

Stone moroko *Pseudorasbora parva* is another small non-native species that has become established in the Mediterranean brackish water systems of Turkey. *Pseudorasbora parva* was captured from 4 stations and it was recorded as new to Beşgöz creek estuary, Kopak creek estuary, and Manavgat river estuary. The first records of *P. parva* in Turkey were reported by Erk'akan (1984) from the Thrace region. Since then, several records of *P. parva* have been reported in Turkey (Yağcı et al., 2014). Stone moroko tolerant to a wide range of salinity and temperature fluctuations, and characterized by early maturation, and establish high-density populations in a short time (Rosecchi et al., 1993; Gozlan et al., 2002; Yegen et al., 2015). *P. parva* has been previously reported in the Antalya Basin (Küçük and İkiz, 2004) and Köprüçay River (Gökoğlu et al., 2001).

In this study, *Oncorhynchus mykiss* was sampled only in Manavgat River Estuary. In Turkey, the first introduction of *O. mykiss* was into Yedigöller (Bolu) National Research Park in 1969 for aquaculture purposes (Uysal and Alpaz 2002). Since 1969 Fry and fingerlings of rainbow trout are released to water bodies by the Ministry of Agriculture and Forestry. In addition to the stocking program, due to their escape from aquatic facilities, *O. mykiss* has become established in some aquatic systems. In Manavgat River, *O. mykiss* was probably established from the farm escape at an aquatic farm located in the estuarine zone of the River.

During the last several decades, over 30 non-native fish species have been introduced to inland water systems of Turkey for different purposes including improvement of fisheries resources, wild stocks and aquaculture, aquarium trade, and biological control. *Carassius gibelio*, *G. holbrooki*, and *O. mykiss* are the most common non-native fish species in the lentic and lotic systems of Turkey. Dispersal areas of *P. parva* have increased recently (Çetinkaya, 2006; İnnal and Erk'akan, 2006; Tarkan et al., 2015; Emiroğlu et al., 2016; Çiçek et al., 2018). Mediterranean brackish water systems are known for their rich biodiversity and economic importance. Besides non-native fish species of freshwater origin, some non-native marine fish have also been identified in this study. Of the 15 localities surveyed Lessepsian fish species were sampled from 9 localities (Beymelek lagoon lake, Kopak creek estuary, Beşgöz creek estuary, Köprüçay river estuary, Manavgat river estuary, Paradeniz lagoon lake, Göksu river estuary, Seyhan river estuary, Ceyhan river estuary).

Seven Lessepsian migrant species of Mediterranean were sampled in studied brackish water systems. The most widely distributed Lessepsian species were *Chelon carinatus*, present in 8 localities, and *Sillago suezensis* which was registered in 4 localities. Within the brackish water systems, the highest number of lessepsian species was observed in the Manavgat River Estuary. The native fish assemblages of brackish water systems analyzed in this study are threatened by introductions of non-native fish species. The negative ecological effects of non-native fish species on native species have been reported (Macdonald and Tonkin, 2008, Cucherousset and Olden, 2011). Non-native fish introductions may result in impacts as a result of one or many undesirable characteristics, including competition, habitat alteration, parasitism, predation, hybridisation, alteration of habitat quality and/or ecosystem function, host of pests or parasites (Copp et al., 2005).

The Mediterranean Sea is considered to be one of the main hotspots of marine bio-invasions on Earth and is by far the major recipient of non-native species among European seas (Kalogirou et al., 2012). Many Lessepsian fish species form dense populations in Mediterranean. Some of them contributed economically to local fishermen. The spread of some species expanded to the Aegean and the Marmara seas. Due to the excessive population density of some poisonous sea fish species, they damage ecosystem and economy (D. Innal, pers. observation). Various aspects of Lessepsian fish ecology (Taşkavak and Bilecenoğlu, 2001, Başusta et al., 2013, Yapıcı and Filiz, 2019, Irmak and Özden, 2020) were examined. However, information about their distribution in brackish water is limited. Reticulated filefish *Stephanolepis diaspros*, Por's goatfish *Upeneus pori*, and Dusky spinefoot, *Siganus luridus*, were reported in the peri-Mediterranean lagoon of Bizerte in northern Tunisia (Bdioui et al., 2004, Azzouz et al., 2010; Ounif-Ben Amor et al., 2016). Black-barred halfbeak *Hemiramphus far* was recorded from Bardawil lagoon, Egypt (Mehanna et al., 2019).

The non-native fish species composition, numbers of species, and dominant species differed between the studied locations. The highest number of non-native species (10) was sampled from the Manavgat River Estuaries. Differences in the non-native fish species composition of the locations may

be due to factors such as sampling procedure, human interventions on aquatic systems, and bioecological characteristics of aquatic systems.

Additional research on the impact of non-native fishes will be beneficial as it will complete and further improve knowledge in this field. The urgent need for management actions to prevent further introductions of non-native species in the Mediterranean brackish water systems appears evident.

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